US007507244B2

United States Patent
(12) United States Patent
Dinkler

(10) Patent No.: US 7,507,244 B2
(45) Date of Patent: Mar. 24, 2009

(54) **RADIOLUCENT SKULL CLAMP WITH REMOVABLE PIN LOAD APPLICATOR**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 808 days.

(21) Appl. No.: **10/774,769**

(22) Filed: **Feb. 9, 2004**

(65) **Prior Publication Data**

US 2005/0075650 A1 Apr. 7, 2005

Related U.S. Application Data

(60) Provisional application No. 60/446,299, filed on Feb. 10, 2003.

(51) **Int. Cl.**
A61B 19/00 (2006.01)

(52) **U.S. Cl.** **606/130**

(58) **Field of Classification Search** 606/130, 606/54, 56, 59; 5/622, 637, 640
See application file for complete search history.

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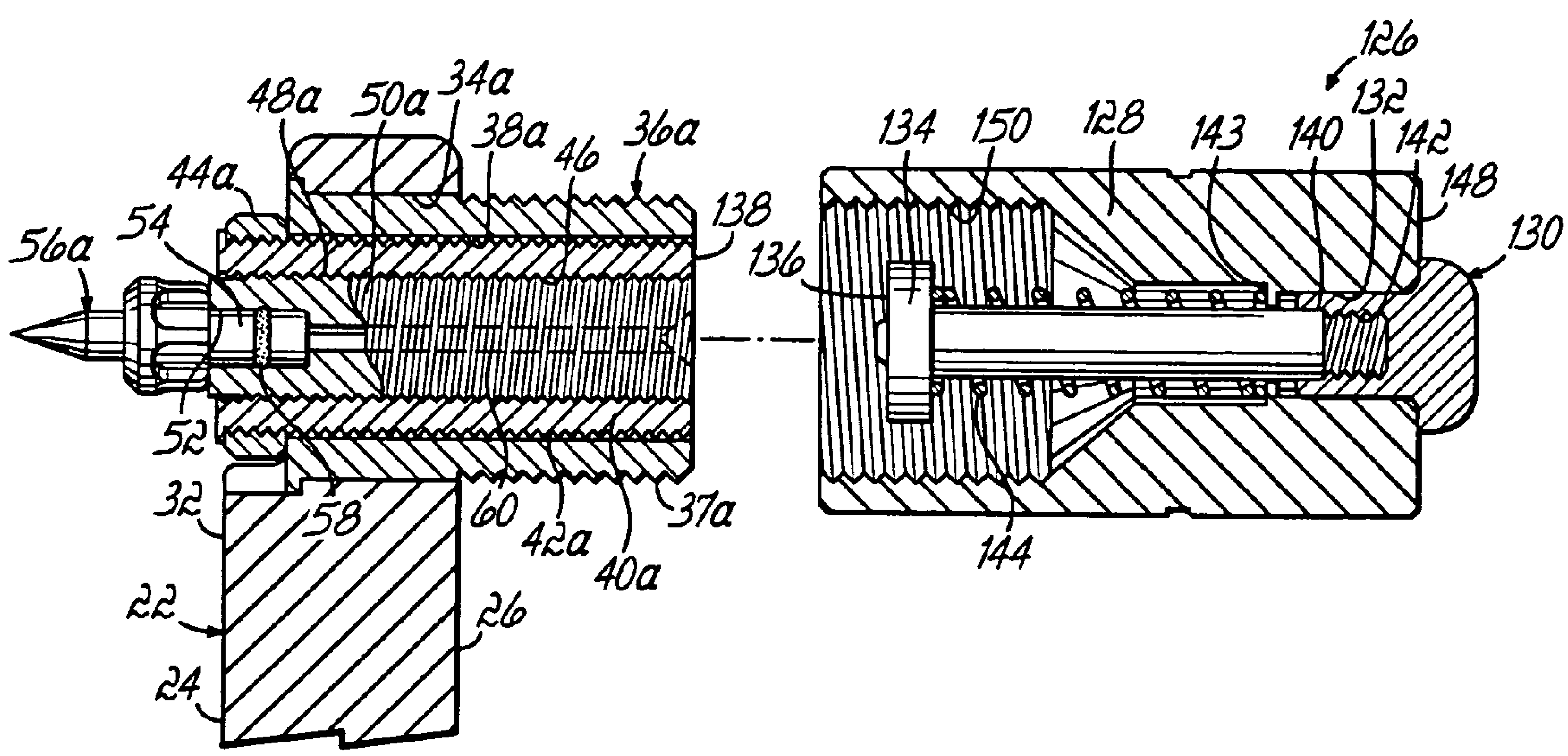
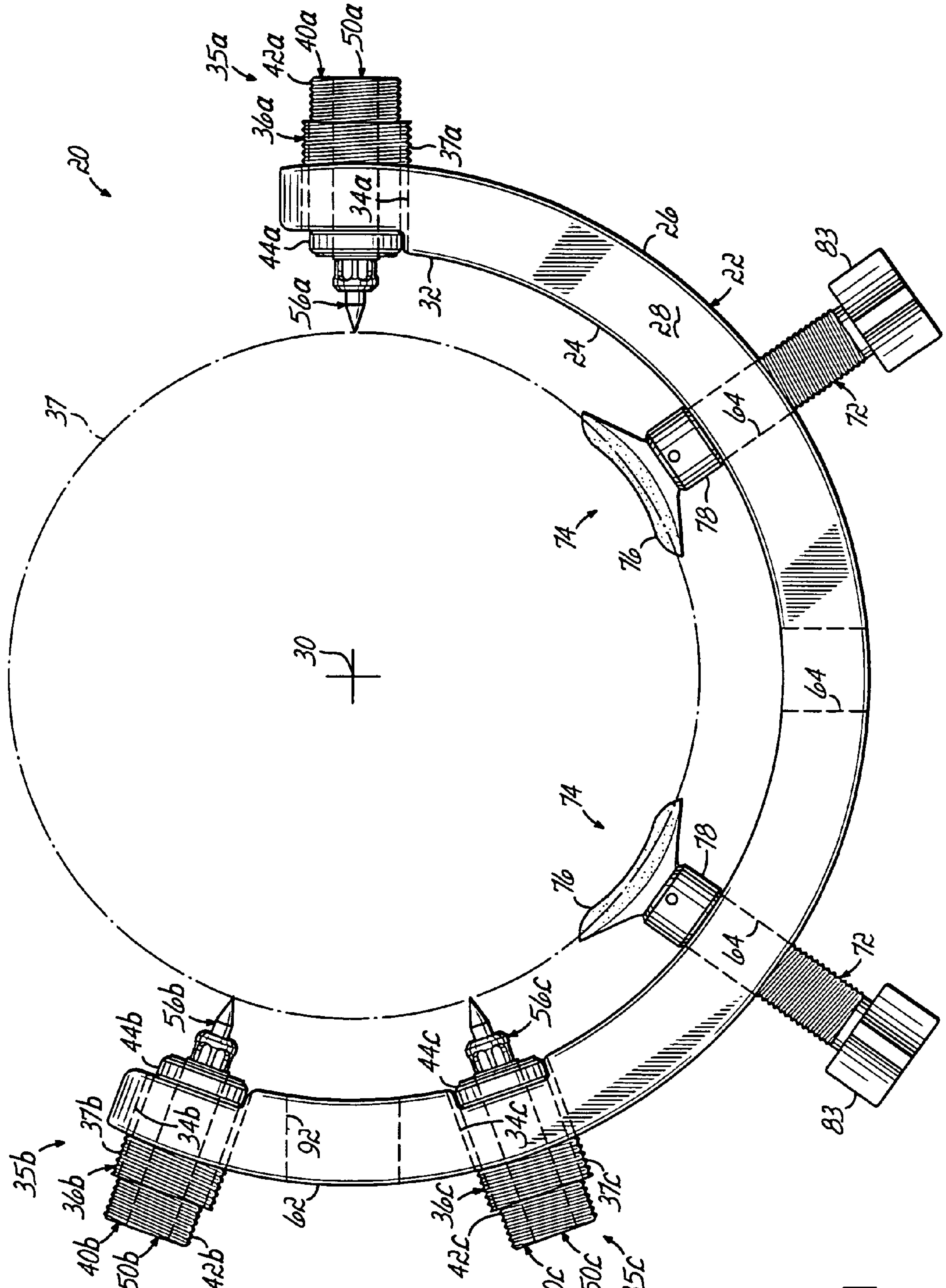
(57) **ABSTRACT**

A skull pin assembly for use with a skull clamp includes a skull pin that is slidable into contact with a head of a patient. A pin load applicator is removably connectable to the skull pin assembly and includes a loading shaft that is able to apply a force against an inner end of the skull pin. The pin load applicator also has a biasing element operable to apply a force on the loading shaft that, in turn, transfers the force to the skull pin. A load force indicator is connected to the loading shaft and provides an indication of the force being applied by the skull pin. The pin load applicator permits the force being applied by the skull pin to be adjusted to a desired value; and thereafter, the pin load applicator is removed from the skull pin assembly without changing the desired skull pin force.

8 Claims, 6 Drawing Sheets

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56c
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44c
37b
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35c

FIG. 1

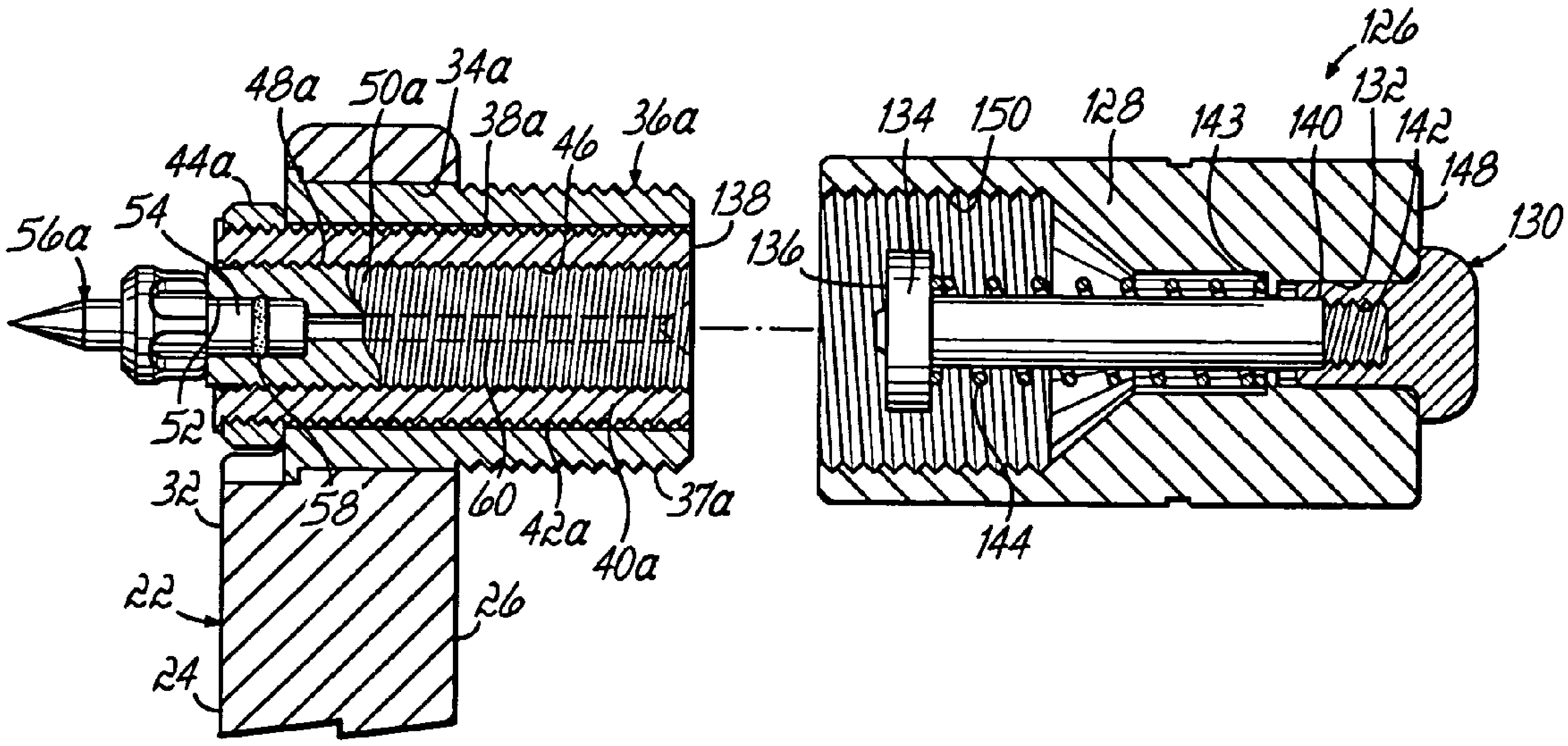
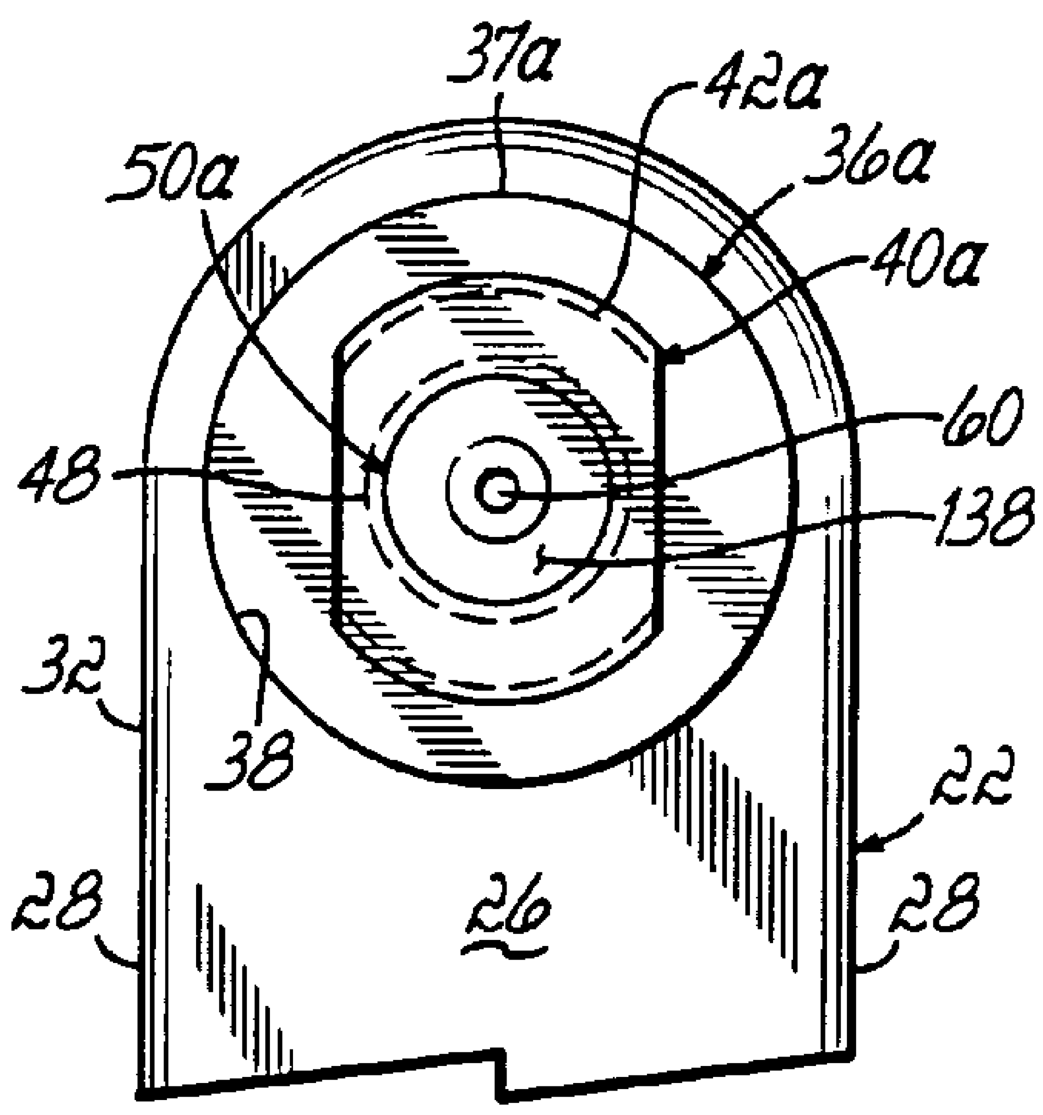


FIG. 2



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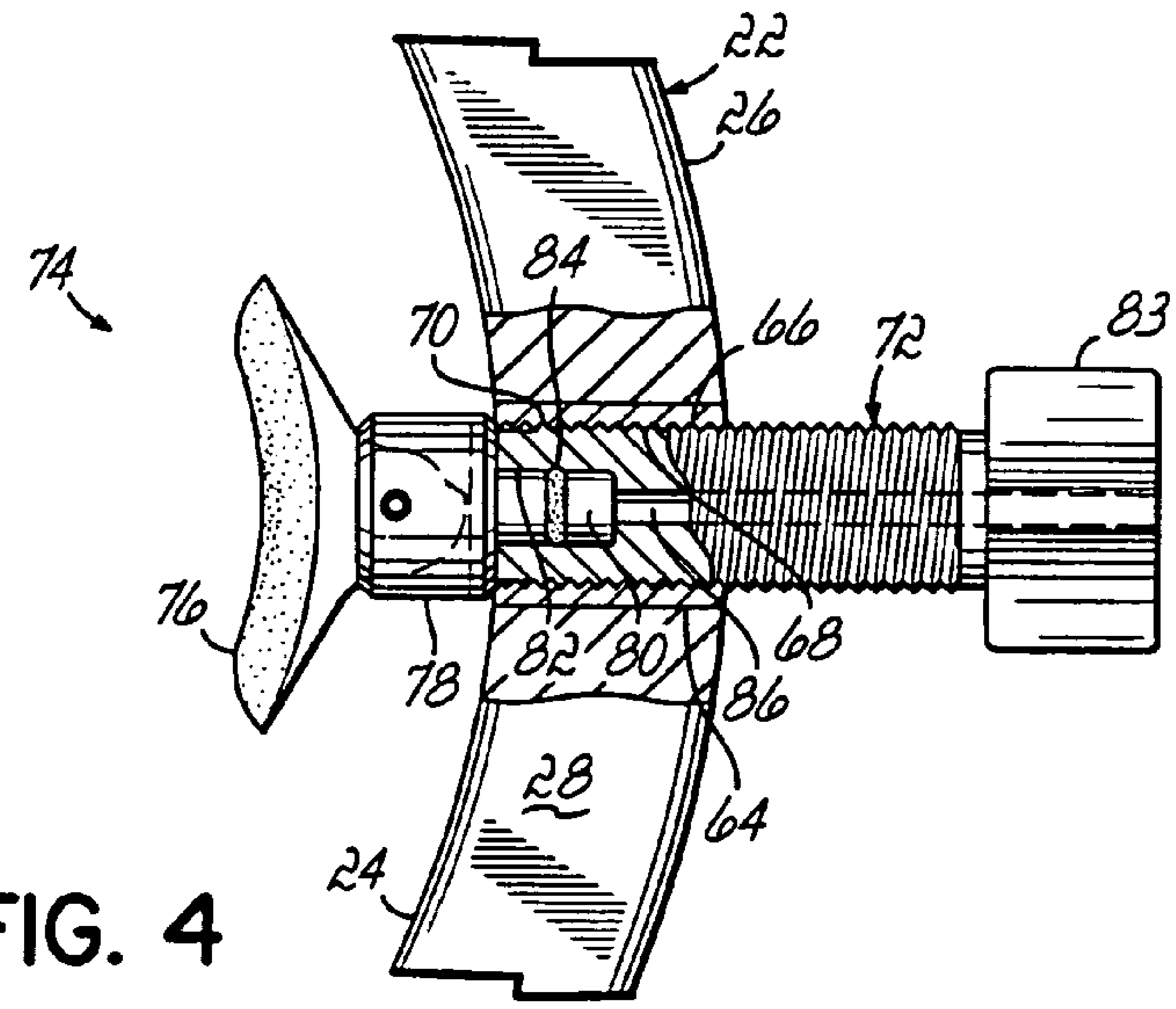

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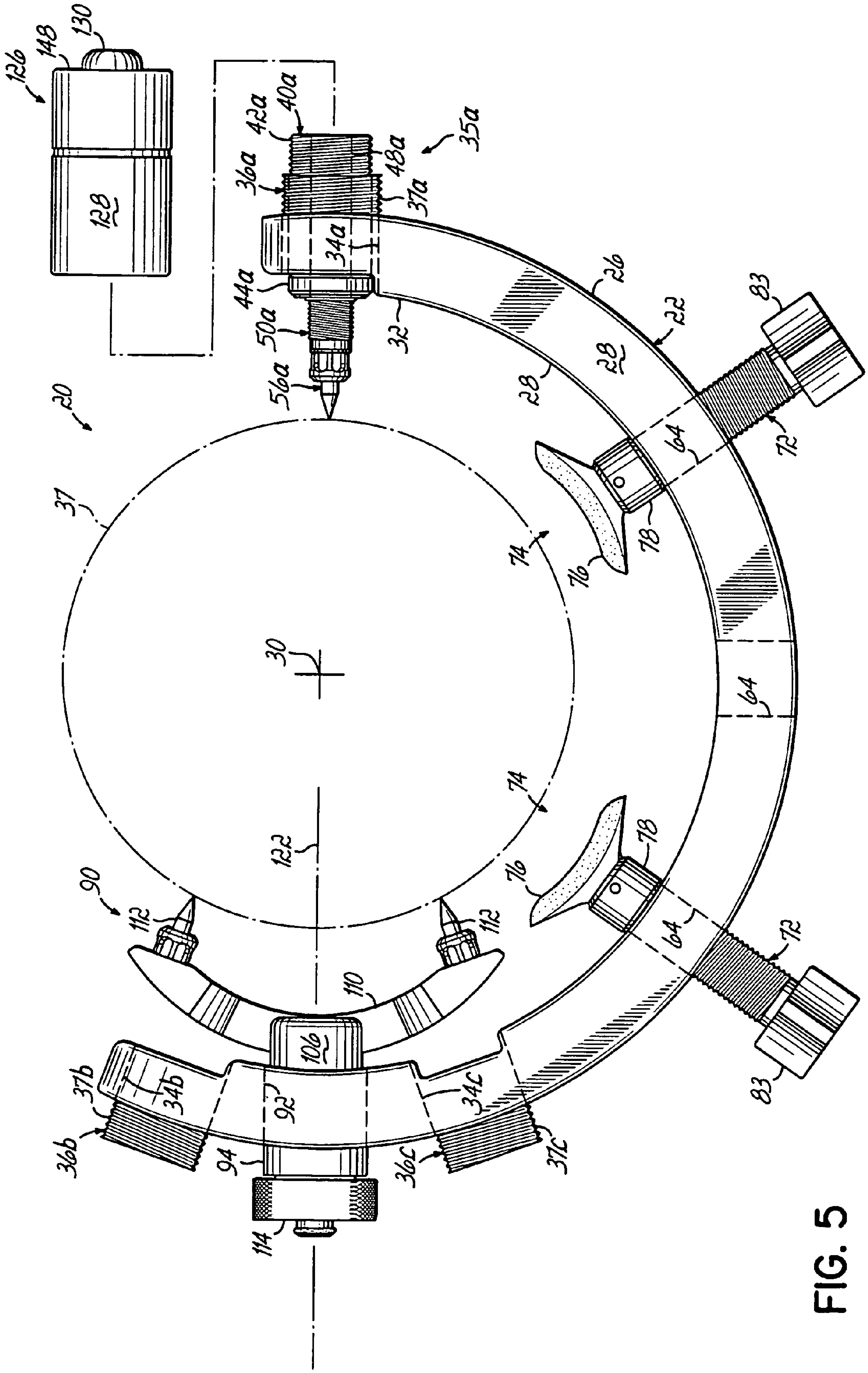
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37
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76
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76
64
72
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122
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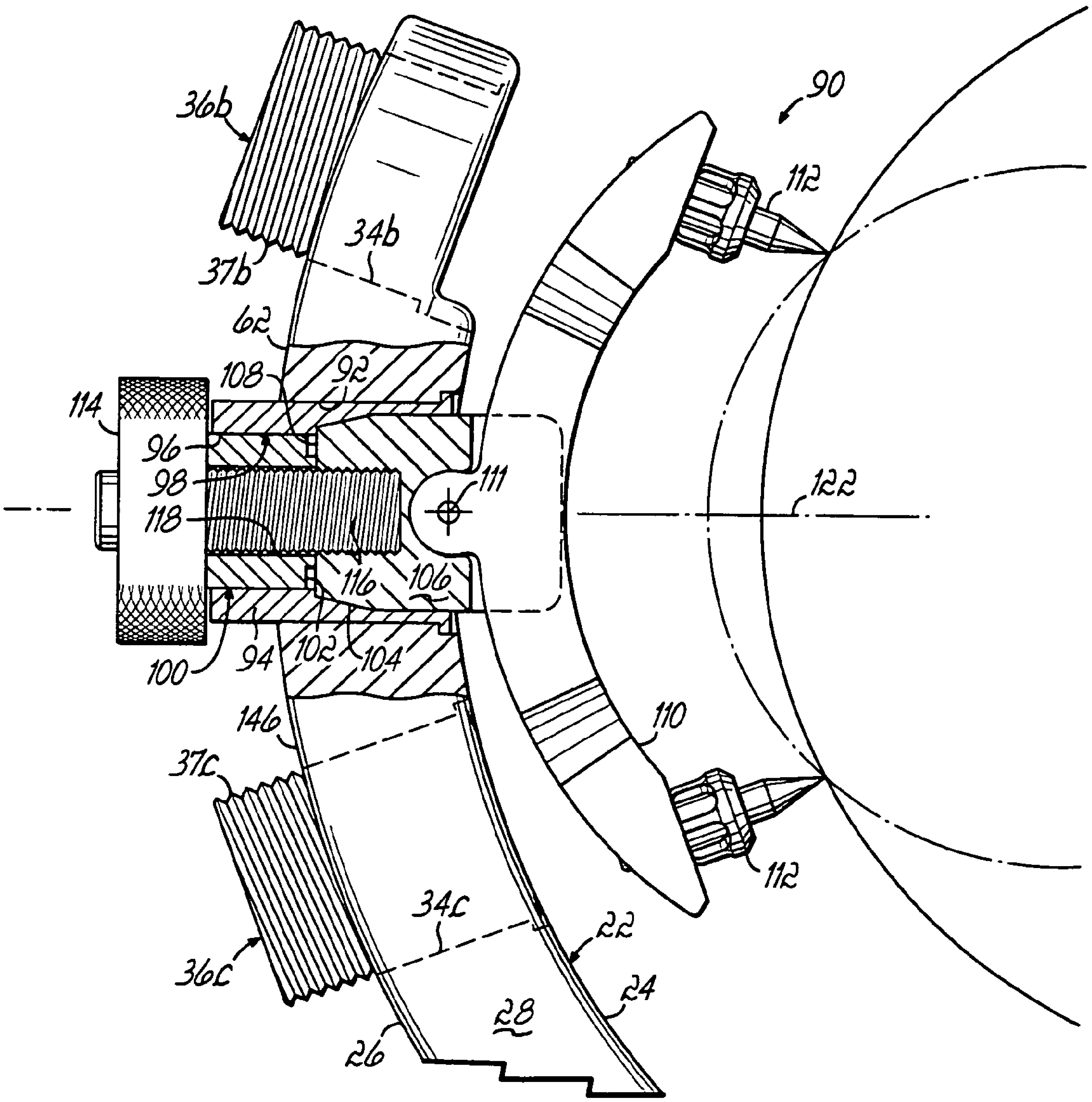
112
112
110
106
34b
37b
92
34c
36b
94
36c
37c
114

FIG. 5



90
112
36b
34b
37b
62
108
92
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96
98
111
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118
116
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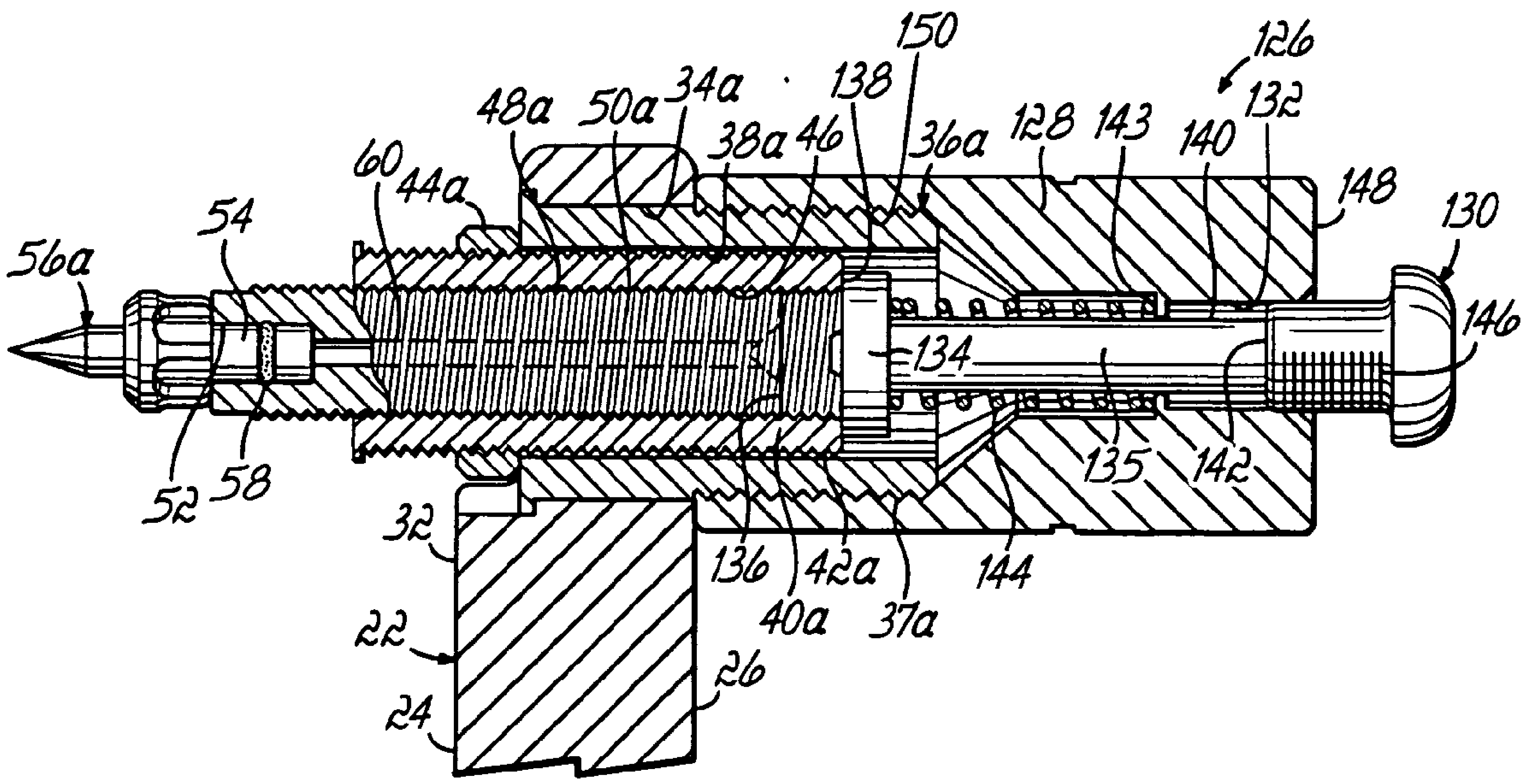
100
94
102
104
110
146
37c
112
34c
22
36c
24
28
26

FIG. 6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40a
37a
22
26
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FIG. 7

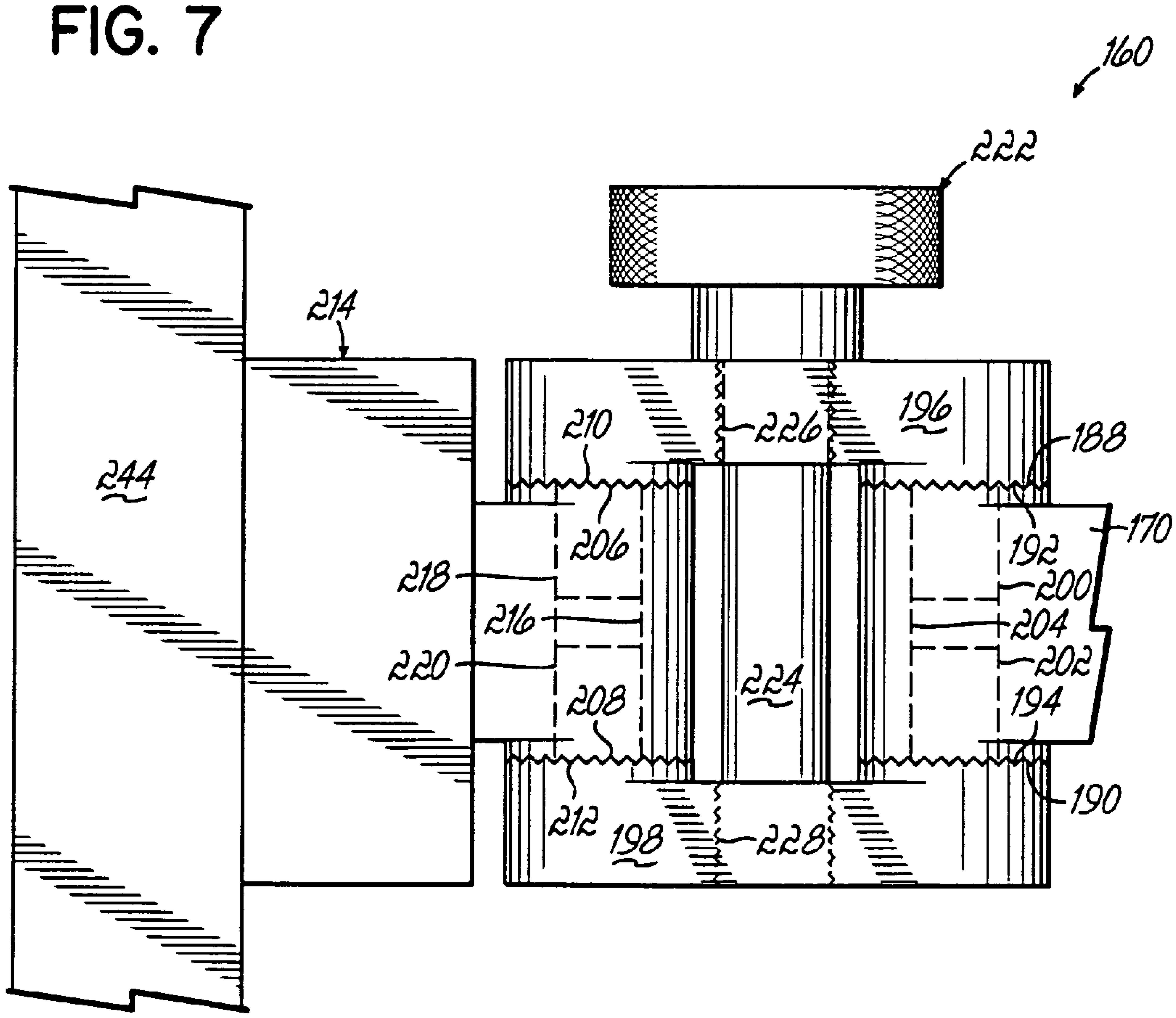
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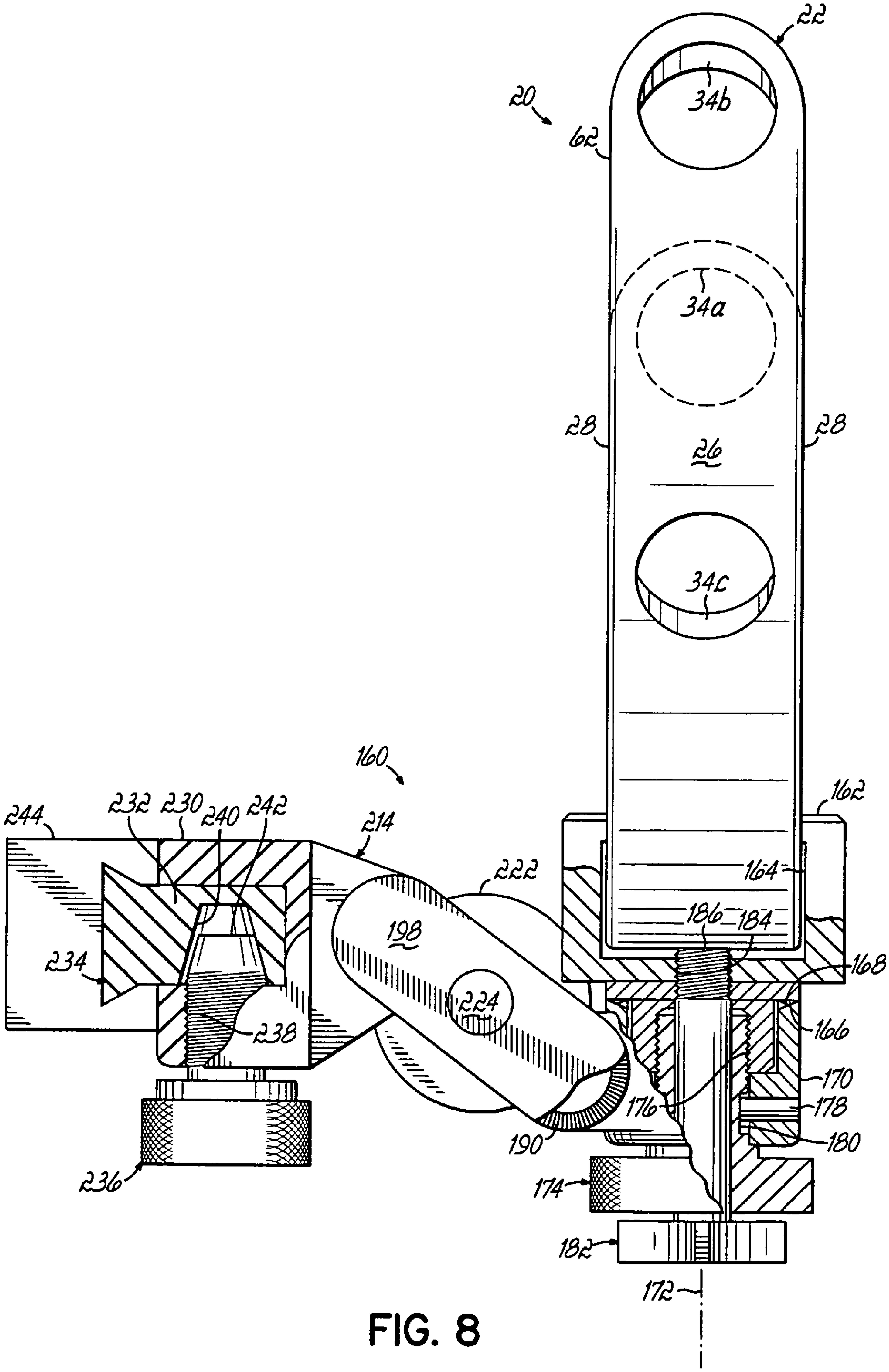
FIG. 9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34b
34a
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34c
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232
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214
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186
184
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224
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166
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236
174
182
172

FIG. 8

RADIOLUCENT SKULL CLAMP WITH REMOVABLE PIN LOAD APPLICATOR

This application claims the benefit of U.S. Provisional Application Ser. No. 60/446,299, filed Feb. 10, 2003.

FIELD OF THE INVENTION

This invention relates generally to neurosurgical apparatus and more particularly, to an improved apparatus for supporting a head of a patient.

BACKGROUND OF THE INVENTION

Generally, cranial stabilization refers to a line of compatible and interconnectable medical devices used during neurosurgery to hold the head of a patient in a fixed position relative to a surgical operating table. A typical arrangement of such products may include, for example, a base unit that connects directly to the surgical table, one or more adaptors connected to the base unit, and a skull clamp connected to an adaptor. The skull clamp often has three skull pins that engage and hold the skull of the patient.

One type of known skull clamp is designed to accommodate all sizes of heads and is comprised of two opposed clamp arms that have proximal ends slidable with respect to each other. A distal end of one clamp arm has a single skull pin, and a distal end of the other clamp arm has a rocker arm with two skull pins. Such a skull clamp and its supporting linear slide mechanism is a relatively large structure. Scanning machines require that a skull clamp and supporting structure be fully radiolucent, as small as possible and still provide flexibility and stability in supporting a patient's skull. One known approach to reducing the size of the skull clamp is to replace the two opposed sliding clamp arms with a radiolucent unitary clamp body structure.

Regardless of the general construction of the skull clamp, three skull pins are used to support the head of a patient. One skull pin is positioned to contact one side of the head; and two skull pins are positioned to contact an opposite side of the head. It is often desirable that the clamping force applied by the skull pins be distributed so that equal and opposite forces are applied to opposing sides of the head. With known designs, a force adjusting screw is threaded through the skull clamp body. A skull pin is inserted with a compression spring in an inner end of the force adjusting screw. Thus, with the skull pin contacting the head, as the force adjusting screw is tightened, the compression spring is compressed; and the skull pin applies an engagement force against the head. The magnitude of the engagement force is determined by the spring constant of the spring. A scale often extends through an outer end of the adjusting screw; and as the adjusting screw is tightened and the engagement force increases, the scale extends past the outer end of the adjusting screw an amount proportional to the engagement force. Thus, by observing the scale, the adjusting screw can be tightened to provide a desired engagement force magnitude.

While the above skull pin and force adjusting screw combination works well, it does have disadvantages. First, the compression spring within the force adjusting screw is made of metal and thus, is not radiolucent. The use of nonradiolucent materials in association with a radiolucent skull clamp body is undesirable and results in artifacts in MRI scans of the head when it is mounted in the skull clamp. Further, the manifestation of such artifacts is unpredictable and may vary from scan to scan, which makes the scanned information more difficult to interpret and use. In addition, the artifacts increase as the number of skull pins with an engagement force indicator increases. In addition, the force adjusting screw and scale extend radially outward beyond the outer perimeter of the skull clamp, which increases the envelope of space required by the skull clamp within the scanning machine.

Thus, there is a need to provide a skull pin force adjusting mechanism that does not have the disadvantages discussed above.

SUMMARY OF THE INVENTION

The present invention provides a skull pin assembly and removable pin load applicator that allows a user to easily set a desired engagement force but is fully radiolucent during an MRI scan. Further, the removable pin load applicator includes the force adjusting screw and can be removed after the engagement force is set, thereby substantially reducing the envelope of space required by the skull clamp within the scanning machine.

According to the principles of the present invention and in accordance with the described embodiments, the invention provides a skull pin assembly slidably mountable on a skull clamp. The skull pin assembly includes a skull pin that is movable to contact the head of a patient. A pin load applicator is removably connectable to the skull pin assembly and includes a loading shaft that is able to apply a force against an inner end of the skull pin. The pin load applicator also has a biasing element operable to apply a force on the loading shaft that, in turn, transfers the force to the skull pin. A load force indicator is connected to the loading shaft and provides an indication of the force being applied by the skull pin contacting the head of the patient. The pin load applicator permits the force being applied by the skull pin to be adjusted to a desired value; and thereafter, the pin load applicator can be removed from the skull pin assembly without changing the desired skull pin force.

In another embodiment, the invention includes a skull clamp having the above-described skull pin assembly and removable pin load applicator. In a further embodiment, the clamp and the skull pin assembly are made of radiolucent materials. Hence, with the metallic biasing element in the pin load applicator removed from the skull pin, there are no artifacts in a subsequent MRI scan attributable to the metallic biasing element. In a still further embodiment, the invention provides a method of using the above-described skull pin assembly and removable pin load applicator.

These and other objects and advantages of the present invention will become more readily apparent during the following detailed description taken in conjunction with the drawings herein.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a plan view of one configuration of a radiolucent skull clamp in accordance with the principles of the present invention.

FIG. **2** is partial cross-sectional view of a skull pin assembly and a removable pin load applicator for the radiolucent skull clamp of FIG. **1**.

FIG. **3** is a plan view of an end of a skull pin mounting using the skull clamp of FIG. **1**.

FIG. **4** is a partial cross-sectional view of a pad screw assembly used with the radiolucent skull clamp of FIG. **1**.

FIG. **5** is a plan view of another configuration of the radiolucent skull clamp of FIG. **1**.

FIG. **6** is a partial cross-sectional view of a rocker arm assembly used with the radiolucent skull clamp of FIG. **1**.

FIG. **7** is a partial cross-sectional view of the removable pin load applicator applied to a skull pin assembly of the radiolucent skull clamp of FIG. **1**.

FIG. **8** is a partial cross-sectional view of a clamp support assembly for the radiolucent skull clamp of FIG. **1**.

FIG. **9** is a partial cross-sectional view of a hinge plate assembly of the clamp support assembly of FIG. **5**.

DETAILED DESCRIPTION OF THE INVENTION

Referring to FIG. **1**, a skull clamp **20** includes an arcuate, single-piece, unitary clamp body **22** that has a generally quadrilateral, for example, a rectangular, cross-sectional profile. The body **22** has an arcuate inner surface **24**, an opposed arcuate outer surface **26** and opposed arcuate side surfaces **28**. The body **22** is generally circular with respect to a center point **30**. One end **32** of the body **22** has a generally radially directed bore **34***a* extending through the inner and outer surfaces **24**, **26** and in which an insert **36***a* is rigidly mounted, for example, by an epoxy, threads or other means. A skull pin assembly **35***a* includes an engagement shaft **40***a* that is slidably mounted within the insert, and a locking nut **44***a* that is mounted on an inner end of the engagement shaft **40***a*. The skull pin assembly **35***a* further includes a skull pin **56***a* inserted in one end of a piston **50***a*, that, in turn, is slidably disposed within the engagement shaft **40***a*. The skull pin assembly **35***a* permits the skull pin **56***a* to be moved into contact with a head or skull of a patient shown schematically by the phantom line **37**.

As shown in FIG. **2**, the insert **36***a* has a smooth internal bore **38** with a noncircular cross section. An engagement shaft **40***a* has external threads **42***a*; and, as shown in FIG. **3**, an external noncircular cross-sectional profile that is similar to, but slightly smaller than, the cross-sectional profile of the engagement shaft bore **38**. Thus, the engagement shaft **40***a* is locked from rotation with respect to the insert **36***a* but, is able to slide linearly in a generally radial direction with respect to the clamp body **22**. The noncircular cross-sectional profiles of the insert bore **38** and the exterior of the engagement shaft **40***a* may be of any noncircular shape that achieves the same result and also permits threads **42***a* to be formed on the exterior of the engagement shaft **40***a*, so that a locking nut **44***a* (FIG. **2**) can be threaded over the engagement shaft threads **42***a*.

Referring to FIG. **2**, the engagement shaft **40***a* has a threaded inner bore **46** that receives threads **48** of a piston **50***a*. The piston **50***a* can be threaded into either end of the engagement shaft **40***a*. The piston **50***a* has an inner end cavity **52** that is sized to receive a shank **54** of a skull pin **56***a*. An O-ring **58** on the skull pin shank **54** provides an interference fit with the end cavity **52** to prevent the skull pin **56***a* from inadvertently sliding out of the piston **50***a*. A central through hole **60** within the piston **50***a* allows air to escape from the cavity **52** when the skull pin **56***a* is mounted within the piston **50***a*.

Referring to FIG. **1**, a second, opposite end **62** of the skull clamp body **22** has a respective pair of generally radially directed bores **34***b* and **34***c* extending through the inner and outer surfaces **24**, **26**. Skull pins **56***b*, **56***c* are mounted in the respective bores **34***b*, **34***c* in a manner substantially identical to the mounting of the skull pin **56***a* described above. Thus, skull pins **56***b*, **56***c* are mounted in the ends of respective pistons **50***b*, **50***c* that, in turn, are threaded into respective engagement shafts **40***b*, **40***c*. The engagement shafts **40***b*, **40***c* are slidably mounted within respective inserts **36***b*, **36***c* that are rigidly mounted within the respective bores **34***b*, **34***c*.

The unitary clamp body **22** has further bores **64** that extend through the inner and outer surfaces **24**, **26** in a generally radial direction with respect to the center point **30**. Referring to FIG. **4**, inserts **66** are rigidly fastened within the bores **64** by epoxy or other means. The outer surface of the inserts **64** may be provided with longitudinal grooves or other texturing such that the epoxy or other adhesive firmly locks the inserts **66** within the bores **64**. Each of the inserts **66** has a threaded through hole **68** that is sized to receive outer threads **70** on a pad adjusting screw **72**. A pad assembly **74** has a resilient pad **76** pivotally mounted to a pad support **78**. A shank **80** extending from the pad support **78** is insertable in an end cavity **82** in an inner end of the pad adjusting screw **72**. An O-ring **84** mounted on the shank **80** is sized to provide an interference fit within the cavity **82**, thereby preventing the support pad assembly **74** from inadvertently dropping off of the pad adjusting screw **72**. A central bore **86** within the pad adjusting screw permits air to escape from the cavity **82** as the shank **80** is inserted therein. Rotation of a knob **83** on an outer end of the pad adjusting screw **72** moves the pad **76** radially toward or away from the center point **30**. Thus, the clamp body **22** permits up to three support pad assemblies **74** to be used to support and stabilize the skull while the skull pins **56** are properly engaged with the skull. Thereafter, the support pad assemblies **74** are backed away from contact with the skull.

FIG. **5** illustrates another configuration of the skull clamp **20**. First, it should be noted that the piston **50***a* in FIG. **5** is longer than the piston **50***a* shown in FIG. **1**. Thus, by using pistons **50***a* of different lengths, a wide range of skull sizes can be accommodated. With some patients or procedures, a surgeon may prefer to utilize a rocker arm assembly **90** on an opposite end **62** of the clamp body **22** in place of the pair of skull pins **56***b*, **56***c* illustrated in FIG. **1**. The pair of skull pins **56***b*, **56***c* can be removed from their respective inserts **36***b*, **36***c* by simply sliding the respective engagement shafts **40***b*, **40***c* toward the center point **30**. The skull clamp body **22** has a further bore **92** that extends through the inner and outer surfaces **24**, **26** at a location that is aligned generally diametrically opposite the bore **34***a* located in the clamp body first end **32**. Referring to FIG. **6**, a rocker arm insert **94** is rigidly fastened within the bore **92** by epoxy or other means. An outer end **96** of an internal bore **98** in the insert **94** has a noncircular cross-sectional profile, for example, a hexagonal shape. A swivel lock **100** has an external noncircular cross-sectional profile that is substantially similar to, but slightly smaller than, the cross-sectional profile of the bore outer end **96**. Thus, when the swivel lock **100** is inserted in the bore outer end **96**, it can slide longitudinally with respect to the bore **98** but is prevented from rotating with respect to the insert **94**. The swivel lock **100** further has on its inner end a toothed connector **102**, for example, a star burst connector comprising a ring of teeth.

The inner end **104** of the insert internal bore **98** has a flared shape that receives an inner end of a rocker arm swivel **106**. A toothed connector **108** is disposed on an outer end of the rocker arm swivel **106** and located opposite the toothed connector **104** on the swivel lock **100**. A rocker arm **110** is pivotally mounted in a clevis at an inner end of the rocker arm swivel **106** in a known manner to pivot with respect to a pivot axis **111**, and skull pins **112** are removably mounted at ends of the rocker arm **110** in a known manner. A knob **114** is threaded on an outer end of a swivel locking screw **116**. The swivel locking screw **116** extends centrally through a clearance hole **118** in the swivel lock **100** and through the toothed connector **108**, and the screw **116** has an inner end that is fixed in a threaded hole in the rocker arm swivel **106**. Thus, turning the knob **114** in one direction moves the knob **114** outward, that is, to the left as viewed in FIG. **6**, thereby removing a clamping force from swivel lock **100** and permitting the swivel lock **100** to move slightly outward with the knob **114**.

The rocker arm connector **108** then disengages from the swivel lock connector **102**, which allows the rocker arm **110** to be rotated with respect to an axis of rotation **122**. When the desired angular position of the rocker arm **110** is achieved, the knob **114** is rotated in an opposite direction, thereby moving it and the swivel lock **100** to the right as viewed in FIG. **6**, which engages the connectors **108** and **102** and secures the rocker arm **110** at its desired angular position.

It is often desirable to be able to tighten one or more of the skull pins **56** shown in FIGS. **1** and **5** to a desired force, so that the skull is held in the skull clamp **20** with a desired clamping force. The skull clamp **20** of the present invention has the capability of controlling the clamping force applied by one or more of the skull pins **56** in all of its configurations. Referring to FIG. **7**, to achieve a desired clamp force with skull pin **56***a*, a removable pin load applicator **126** is threaded onto the external threads **37** of the insert **34***a*. The removable pin load applicator **126** is comprised of a knob **128** that resiliently supports a load force indicator **130** extending through a center hole **132** of the knob **128**. A plunger **134** on one end of a loading shaft **135** has an outer surface **136** that contacts an outer end **138** of the engagement shaft **40***a*. An opposite end **140** of the loading shaft **135** is threaded into an inner end **142** of the load force indicator **130**. A biasing means **144**, for example, a compression spring, extends between the plunger **134** and an internal surface **143** within the knob **128**.

The knob **128** has internal threads **150** that mate with the external threads **37** on the insert **36**. As the knob **128** is tightened over the insert **36**, the plunger distal end **136** contacts the engagement shaft outer end **138** and pushes the engagement shaft **40***a* until the skull pin **56***a* contacts the patient's head. Continued tightening of the knob compresses the spring **144**, which applies a reactive force against the engagement shaft **40***a* that, in turn, causes the skull pin **56***a* to apply the reactive force against the patient's head. Further tightening of the knob **128** increases the clamping force applied by the skull pin **56***a*. The force compressing the spring **144** shortens the spring **144** and causes the load force indicator **130** to move outward away from the surface **148**. The outer surface of a shank portion of the load force indicator **130** contains annular markings **146** that dimensionally represent a force being applied by the skull pin **56***a*. When one of the force indicator rings **146** is moved to a position adjacent the surface **148**, a force represented by that indicator ring is being applied by the skull pin **56***a* against the skull. The knob **128** is tightened until a desired force is achieved as represented by the appropriate force indicating ring **146** being positioned with respect to the surface **148**. At that point, the locking nut **44** is rotated until it contacts the inner surface **24** of the clamp body **22**. The knob **128** is then loosened, and the removable pin load applicator **126** is removed from the insert **36**. The locking nut **44** holds the engagement shaft **40** in a position that applies the desired force against the skull via the skull pin **56***a*. As will be appreciated, the knob **128** can be used in the same manner to adjust the forces applied by skull pins **56***b* and **56***c*.

Referring to FIGS. **8** and **9**, the skull clamp **20** is mounted to a dovetail rail **244** on a patient support by means of a skull clamp support assembly **160**. A clamp support bracket **162** has an internal opening **164** with a cross-sectional shape substantially similar to, but slightly larger than, the cross-sectional profile of the clamp body **22**. The clamp support bracket **162** also has a toothed connector **166** that is located adjacent to a mating toothed connector **168** on a swivel adaptor **170**. Thus, the clamp support bracket **162** and clamp body **22** are able to pivot with respect to the swivel adaptor **170** and about an axis of rotation **172**. A swivel locking screw **174** extends through an internal through hole in the swivel adaptor **170** and is threaded into an end cavity **176** in the lower end of the clamp support bracket **162**. A pin **178** is mounted in the swivel adaptor **170** and extends into an annular groove **180** in the swivel locking screw **174**. Therefore, the swivel locking screw **174** is able to rotate freely within the swivel adaptor **170** but cannot be removed therefrom. Further, rotation of the swivel locking screw **174** in one direction causes the support bracket connector **166** to separate from the swivel adaptor connector **168**, thereby permitting the clamp support bracket **162** and clamp body **22** to be rotated with respect to the swivel adaptor **170**. Turning the swivel locking screw in the opposite direction engages the connectors **166** and **168**, thereby firmly securing the clamp support bracket **162** and clamp body **22** in a desired angular position with respect to the swivel adaptor **170**.

A position locking screw **182** extends through the swivel locking screw **174** and the swivel adaptor **170** and engages a second threaded bore **184** in the lower end of the clamp support bracket **162**. Rotating the position locking screw **182** in one direction forces an end face **186** of the screw against a side **26** of a clamp body **22**, thereby locking the clamp body **22** within the clamp support bracket **162**. Turning the position locking screw **182** in the opposite direction disengages the end surface **186** from the clamp body side **28** and permits the clamp body **22** to move freely through the opening **164** in the clamp support bracket **162**.

Referring to FIG. **9**, the swivel adaptor **170** has opposed toothed connectors **188**, **190** that are located opposite opposed toothed connectors **192**, **194** at one end of first and second hinge plates **196**, **198**, respectively. The hinge plates **196**, **198** have respective pins **200**, **202** that extend into opposite ends of a bore **204** extending through the swivel adaptor **170**. Opposite ends of the hinge plates **196**, **198** have respective toothed connectors **206**, **208** that are located opposite toothed connectors **210**, **212** of a dovetail adaptor **214**. The dovetail adaptor has a through hole **216** that receives pins **218**, **220** of the first and second hinge plates **196**, **198**, respectively. A hinge locking screw **222** has a smooth shaft **224** that extends through a threaded hole **226** of the first hinge plate **196**. A distal end of the smooth shaft **224** is threaded and engages a threaded hole **228** of the second hinge plate **198**. Thus, rotating the hinge locking screw **222** in the first direction disengages the opposed pairs of connectors **188**, **192**, **190**, **194**, **206**, **210** and **208**, **212**; and the swivel adaptor **170** and the dovetail adaptor **214** are able to rotate freely with respect to each other. Rotating the hinge locking screw **222** in the opposite direction engages the opposed pairs of connectors, thereby securing the swivel adaptor **170** and the dovetail adaptor **214** at desired angular positions with respect to each other.

Referring back to FIG. **8**, the dovetail adaptor **214** has a U-shaped end **230** that receives a tongue **232** of a dovetail **234**. A dovetail locking screw **236** extends through a threaded hole **238** of the U-shaped end **230** and into a cavity **240** of the tongue **232**. Thus, rotating the dovetail locking screw **236** in one direction displaces a distal end **242** of the dovetail locking screw **236** away from the cavity **240**, thereby allowing the dovetail **234** to be removed from the dovetail adaptor **214**. Turning the dovetail locking screw **236** in the opposite direction causes its distal end to contact walls of the cavity **240**, thereby securing the dovetail **234** in the dovetail adaptor **214**. The dovetail **234** is insertable and lockable in a dovetail rail **234** in a known manner.

In use, a patient is positioned on an operating table and/or table extension in a known manner; and the patient's head is located generally within the clamp body **22**. The surgeon is then able to manipulate the skull clamp **20** and the patient's head to a desired position using various adjustments on the clamp support assembly **160** described above with respect to FIG. **8**. Prior to setting the skull pin clamping force, the lengths of the pistons **50** are chosen such that the skull pins can simultaneously contact the patient's head, while a substantial portion of the pistons **50** remain threaded within the respective engagement shafts **40**. Various configurations of pins **56** and the rocker arm pins **112** can be used to support the head in a wide range of positions. Further, the pads **74** are used to support and stabilize the patient's head in a desired position while the pins **56** are tightened to a desired clamping force. Thereafter, the pads **74** are moved out of contact with the patient's head.

To achieve a desired clamping force, as described with respect to FIG. **7**, the removable pin load applicator **126** is first mounted on the insert **36***a* and used to apply the desired clamping force with the skull pin **56***a*. Next, the removable pin load applicator **126** is removed from the insert **36***a* and mounted on one of the opposed inserts, for example, the insert **36***b*. The knob **128** is tightened until the respective locking nut **44***b* just begins to move. That torque reading for the skull pin **56***b* is recorded, and the removable pin load applicator **126** is then mounted on the other opposed insert **36***c*. Again, the knob **128** is tightened until the respective locking nut **44***c* just begins to move. The torque reading for the skull pin **56***c* is read and compared to the torque reading for the skull pin **56***b*. If the torque readings are not substantially equal, the removable pin load applicator **126** can be used in association with one or both of the inserts **36***b*, **36***c*; and the knob **128** tightened or loosened in order to bring the forces applied by the skull pins **56** to their desired values.

The skull pin assemblies **35** are often made from commercially available radiolucent materials, for example, "DELRIN", "PEEK", "ULTEM", phenolic and/or sapphire radiolucent materials, that produce a minimum of artifacts during an MRI scanning process. When so made, the skull pin assemblies **35** with the removable pin load applicator **126** have several advantages. First, with the removable pin load applicator **126** removed, all of the skull pin assemblies **35** have the capability of applying respective desired measurable clamping forces against the skull while producing substantially the same artifacts during the MRI scanning process as radiolucent skull pins that do not have that capability. Second, as shown in FIG. **2**, with the pin load applicator **126** removed, the skull pin assemblies **35** have a projection beyond the outer perimeter of the head clamp **22** that is substantially less than known skull pin and force adjusting screw combinations. Further, the pistons **50** can be made with a range of different lengths, so that the skull clamp **20** can be used with a wide range of different head sizes.

While the invention has been illustrated by the description of one embodiment and while the embodiment has been described in considerable detail, there is no intention to restrict nor in any way limit the scope of the appended claims to such detail. Additional advantages and modifications will readily appear to those who are skilled in the art. While the skull pin assemblies **35** and the removable pin load applicator **126** have been shown and described with respect to a single piece skull clamp body **22**, as will be appreciated, the skull pin assemblies and the removable pin load applicator **126** can be used with skull clamps of other designs, for example, a skull clamp having opposed arms that are movable relative to each other. The particular design or type skull clamp shown and described herein is not to be considered a limitation on the inventions claimed.

Further, in the described embodiment, the biasing means **144** is a compression spring, but as will appreciated, in alternative embodiments, other resilient devices may be used for the biasing means **144**.

In the described embodiments, the engagement shaft **40** is slidable within the insert **36**; and the removable pin load applicator **126** is threaded onto the insert **36**. As will be appreciated, in an alternative embodiment, the engagement shaft can be threaded into the insert; and the removable pin load applicator removably connected to the outer end of the engagement shaft, for example, by a twist and lock connection. Therefore, turning the pin load applicator rotates the engagement shaft with respect to the insert; and moves the skull pin into contact with the head of the patient. The pin load applicator is further rotated until the load indicator indicates that the skull pin is applying a desired force against the patient's head. Thereafter, the pin load applicator is removed from the engagement shaft. The threaded engagement between the engagement shaft and the insert prevents the skull pin from moving away from the patient's head; and the desired skull pin force is maintained. A locking nut may also be used to secure the engagement shaft from rotation.

Therefore, the invention in its broadest aspects is not limited to the specific details shown and described. Consequently, departures may be made from the details described herein without departing from the spirit and scope of the claims which follow.

What is claimed is:

1. An apparatus for use with a radiolucent skull clamp supporting a head of a patient comprising:
- a skull pin assembly adapted to be mounted to the skull clamp, the skull pin assembly comprising
- a skull pin adapted to be movable into contact with the head of the patient;
- an engagement shaft adapted to be slidable but not rotatable with respect to the skull clamp;
- a lock nut threaded on an inner end of the engagement shaft to limit slidable motion of the engagement shaft in a direction extending outward from the skull clamp;
- an insert adapted to be mounted to the skull clamp the insert receiving and supporting the skull pin assembly; and
- a pin load applicator adapted to be removably connectable to the skull clamp comprising
- a loading shaft in mechanical communication with the skull pin,
- a biasing element operable to apply a force on the loading shaft, the loading shaft in turn transferring the force to the skull pin contacting the head of the patient, and
- a load force indicator connected to the loading shaft and providing an indication of the force being applied by the skull pin contacting the head of the patient, the loading shaft, the biasing element and the load force indicator being contained in a unitary component that is connectable to and disconnectable from the skull clamp as a single component, the pin load applicator being movable to adjust the force applied by the skull pin contacting the head of the patient, and thereafter, the pin load applicator being removable from the skull clam without changing the force being applied by the skull pin contacting the head of the patient.

2. The apparatus of claim **1** wherein the skull pin assembly further comprises a piston supported by the engagement shaft and connected to the skull pin.

3. The apparatus of claim **2** wherein the piston is threaded within the engagement shaft and movable to change a length of the skull pin assembly.

4. The apparatus of claim **2** wherein the skull pin is supported by an inner end of the piston.

5. An apparatus for use with a radiolucent skull clamp supporting a head of a patient comprising:

a skull pin assembly adapted to be mounted with respect to the skull clamp, the skull pin assembly comprising a skull pin adapted to be movable into contact with the head of the patient and a holder for holding the skull pin;

a lock mounted on and adjustable relative to the holder, the lock operable to prevent movement of the skull pin away from the head of the patient;

a pin load applicator removably connectable to the skull pin assembly and comprising a loading shaft in mechanical communication with the skull pin via the holder,

a biasing element operable to apply a force on the loading shaft, the loading shaft in turn transferring the force via the holder to the skull pin contacting the head of the patient, and

a load force indicator connected to the loading shaft and providing an indication of the force being applied by the skull pin contacting the head of the patient, the pin load applicator being movable to adjust the force applied by the skull pin contacting the head of the patient, so that the lock can then be adjusted relative to the holder so as to maintain said applied force, and thereafter the pin load applicator being removable from the skull pin assembly without changing said applied force being applied by the skull pin contacting the head of the patient.

6. The apparatus of claim **5** wherein said radiolucent skull clamp includes at least two such skull pin assemblies arranged on substantially opposite sides of the patient's head.

7. The apparatus of claim **5** wherein the pin load applicator connects to the skull pin assembly outboard of the skull clamp and the lock is located inboard of the skull clamp.

8. The apparatus of claim **5** wherein the holder has external threads and the lock is a nut sized to threadably engage the external threads of the holder.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE
CERTIFICATE OF CORRECTION

PATENT NO. : 7,507,244 B2
APPLICATION NO. : 10/774769
DATED : March 24, 2009
INVENTOR(S) : Charles E. Dinkler

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

On the Title Pg. Item (74) reads “Wood, Herron & Evans LLP” and should read “Wood, Herron & Evans, L.L.P.”

Col. 8, lines 40-41 Claim 1 [11] reads “. . .mounted to the skull clamp the insert receiving and supporting. . .” and should read “. . .mounted to the skull clamp, the insert receiving and supporting. . .”

Col. 8, line 58 Claim 1 [11] reads “. . .from the skull clam without changing. . .” and should read “. . .from the skull clamp without changing. . .”

Signed and Sealed this

Third Day of November, 2009

David J. Kappos

David J. Kappos
Director of the United States Patent and Trademark Office